Episodic Upwelling of Zooplankton within a Bowhead Whale Feeding Area near Barrow, AK

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LONG-TERM GOALS

Our long term goals are to understand (1) the biological-physical oceanographic characteristics and mechanisms on the shelf near Barrow, AK that together produce a favorable feeding environment for the bowhead whale there and (2) the potential impact of climate change, particularly the ongoing reduction in sea ice and variability in Pacific water presence near Barrow, on this feeding environment. This region is a critical feeding area for migrating bowhead whales, particularly during the fall migration (e.g., Lowry et al., 2004). Results from biophysical sampling conducted during August-September 2005- 2007 demonstrated that the oceanography of the shelf is complex, dynamic, and highly variable and that advection is closely coupled to the direction and magnitude of the winds. In addition, oceanographic and atmospheric conditions impact the composition, distribution, and availability of plankton prey for the bowhead whale. Assessment and understanding of interannual and longer-term variability in the physical mechanisms influencing ocean conditions and the resulting distribution and abundance of plankton on the shelf are necessary to predict potential impacts of climate change.

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14. ABSTRACT

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OBJECTIVES

Our overall objectives are to explicitly identify and document the occurrence, frequency, and persistence of wind-driven shelf-slope exchange events at the Barrow Canyon and the Beaufort shelf breaks during the summer and early fall in association with the presence of ice cover, water column stratification, and the presence of bowhead whales and to further document short-term and interannual variability in the ocean system and how this variability is associated with changes in climate and ice.

1. Document exchanges of Pacific Water and plankton/krill (acoustic backscatter as a zooplankton proxy) between Barrow Canyon and the adjacent Beaufort shelf over two full years.

2. Document shelf-slope exchanges between the Beaufort Sea and Beaufort shelf.

3. Determine the seasonal occurrence of bowhead whales in the study area via year-round sampling for marine mammal vocalizations using autonomous recorders.

4. Determine the correlations between exchange events and wind speed and direction, wind duration, ice cover, shelf water column stratification, whale presence or absence, and whale prey selection.

5. Conduct surveys along transects running across Barrow Canyon and across the shelf to ground-truth mooring observations and to continue the two-year time series of observations collected during the larger, NSF funded project to further describe interannual variability and hydrographic and associated biological characteristics on the shelf during early September and to provide critical information for validation of oceanographic modeling of the region.

APPROACH

This project is a partnership between the academic PIs listed above (Ashjian, Campbell, Okkonen, and Stafford), collaborators at Oregon State University (B. Sherr and E. Sherr), a collaborator at NOAA (S. Moore), and a collaborator at the North Slope Borough Department of Wildlife Management (C. George).

The objectives are being addressed through three main field approaches: Boat Based Oceanographic Sampling (Task 1), Year-Long Oceanographic Moorings (Task 2), and Bowhead Whale Prey Analysis (Task 3). Data analysis and presentation of results (Task 4) and Outreach (Task 5) are accomplished simultaneously with the three work approaches.

WORK COMPLETED

Boat-based oceanographic sampling was conducted from August 17 – August 28, 2008 using the *R/V Annika Marie*. Surveying was conducted primarily across two –transects co-located with transects previously established during 2005/2006 NSF sponsored and 2007 NOAA/WHOI/UAF sponsored fieldwork. Results from these two transects, each of which was surveyed twice, are good indicators of the hydrographic and biological/chemical conditions on the shelf and in adjacent Barrow Canyon (Figure 1). . Continuous sampling was conducted on the outward leg of each transect using a towed

vertically profiling Acrobat vehicle equipped with CTD, optical backscatter sensor, and chlorophyll and CDOM fluorometers and using a towed Teledyne/RDI 300 kHz acoustic Doppler current profiler (ADCP). On the inbound leg of each transect, directed sampling using CTD, Nisken bottles, Video Plankton Recorder (VPR), and plankton nets was conducted a locations selected on the basis of hydrographic and biological features (e.g., fronts, chlorophyll maxima) identified in sections described from the outbound leg data. Water for nutrient and chlorophyll a concentrations and for flow cytometry analysis was collected using Nisken bottles. Mesozooplankton were collected using oblique tows with a ring net equipped with 200 or 500 μm mesh nets and a time-depth recorder. Marine mammal, and to the extent possible, bird locations were enumerated on the transects. On the two days when weather precluded using the towed instruments, additional sampling off of the established transect lines was conducted at discrete stations using CTD, VPR, and plankton nets along the 15-m isobath on the shelf and across the shelf break to better constrain the physical and biological distributions. Altogether 49 stations and 16 hours of towing were conducted during ~70 hours on the water over 6 days.

A pair of year long oceanographic moorings, also equipped with acoustic recorders, were deployed in early August from the *USCGC Healy* (cruise HLY0804) in collaboration with the NOPP project of R. Pickart (see Pickart NOPP report for additional details). To decrease the possibility of ice scouring over winter, the instruments were deployed in 100 m of water in the Beaufort Sea (Figure 2). Both moorings were instrumented, bottom to top, with an acoustics recorder to archive marine mammal vocalizations, microcat CT sensor to measure water temperature and salinity, and HOBO ProV2 temperature sensors at 75 m, 50 m, 40 m, 30 m, 25 m, 20 m depths (Figure 3). The eastern mooring was also instrumented with upward-looking Teledyne/RDI 300 kHz ADCP to aid in monitoring the movement of zooplankton between the slope and shelf. The acoustics recorder is programmed to sample at 8192 Hz on a duty cycle of 9 min/30 min so that a full year's data can be obtained on a 160 Gb hard drive. The moorings will be recovered and redeployed during summer 2009. A third, short-term, bottom mounted mooring was deployed by the *R/V Annika Marie* at the edge of Barrow Canyon on August 22 and recovered on September 9. This mooring was instrumented with an upward-looking Teledyne/RDI 300 kHz ADCP and a SeaBird microcat CTD to investigate the relationship between the overlying wind field, shelf currents, particularly upwelling currents, and the presence of zooplankton by using ADCP backscatter as a proxy for zooplankton.

Bowhead whale prey analysis will be conducted by C. George during fall whaling that commenced on October 6, 2008. George will work with local whalers to sample the stomach contents of landed whales during this IWC sanctioned hunt.

RESULTS

Ocean temperatures were much colder this year, closer to conditions observed in 2006 than in 2005 and 2007. Significant year-to-year variability in the temperature-salinity characteristics of the waters sampled within the Barrow Canyon-western Beaufort shelf study area has been observed over the past four years (2005-2008) (Figure 4). The 2005 and 2007 surveys encountered very warm Pacific Water, whereas the 2006 and 2008 surveys encountered much cooler Pacific Water. The presence of extensive sea ice cover in 2006 is reflected in the prevalence of sea ice meltwater.

Winds were low and from the W and N during the first portion of our 2008 field season, precluding upwelling of water and krill along the Beaufort Shelf (Figure 5). However, upwelling favorable winds did occur from August 30 – Sept. 8 (moderate to strong winds from the E and SE), during which

period we were unable to work because of the adverse weather. Visual examination of the plankton from the net tows revealed few krill this year, despite the period of upwelling favorable winds (although some krill were observed following the period of east wind; the net samples must be enumerated before strong conclusions can be made). An extremely thick layer of high-fluorescing phytoplankton was observed below the pycnocline in Barrow Canyon, with still elevated abundances of low-fluorescing phytoplankton (*Chaetoceros debilis*) in the upper water column as well (observed with the Video Plankton Recorder (VPR)). This high abundance of phytoplankton clogged the plankton nets (even the coarse 500 μm mesh net), precluding effective sampling in Barrow Canyon with the nets (although copepod and other plankton and particle abundances were obtained with the VPR).

Preliminary results from the shallow water mooring at Barrow Canyon show association between the winds and both current direction and diel vertical migration inferred from acoustic backscatter (Figure 5). For the first part of the record, winds were generally weak and from the N – NE and currents over the canyon were to the east. However, acoustic backscatter during that period was low, suggesting few zooplankton (krill) were present. Winds began to blow from the E - SE on about 30 August. Acoustic backscatter plots showing elevated backscatter events peaking a couple of hours after midnight suggested that diel migration of zooplankton began about three days after the onset of E-SE winds on the evening of 1 September. This is consistent with a hypothesis predicting that upwelling along the Beaufort Shelf (rather than Barrow Canyon) during E-SE winds would advect krill onto the shelf that subsequently are concentrated on the shelf along Barrow Canyon.

IMPACT/APPLICATIONS

Our work will provide a greater understanding of the physical and biological factors that produce a favorable feeding environment for the bowhead whale on the shelf near Barrow. This will permit educated decisions regarding development of industry, tourism, and commerce in this region by regulators and policy makers. The work also will provide greater insight into the potential impact of climate change on the Arctic ecosystem. In addition, the continued documentation of interannual variability of the ocean conditions is of both local (importance to shelf ecosystem) and broader importance since the region near Barrow is a critical juxtaposition of the Chukchi Sea and Beaufort Seas and is where much of the Pacific Water flowing through the Chukchi Sea from Bering Strait enters the Beaufort Sea, either through Barrow Canyon or from more western locations in the Chukchi Sea. The Pacific Water supplies heat, nutrients, and organic material including plankton (especially the krill that are the preferred prey of the bowhead whale near Barrow) to the Chukchi Sea and ultimately the Arctic Ocean.

RELATED PROJECTS

This ongoing project is a follow on to a previous National Science Foundation funded project examining “Oceanography, Bowhead Whale Distribution, Climate Variability, and Iñupiate Subsistence Whaling”, with PIs including Ashjian, Campbell, George, Moore, Okkonen, Sherr, and Sherr for which fieldwork was conducted in 2005 and 2006. Many of the hypotheses being explored in this project resulted from data collected during the NSF project. The ongoing project also is a companion to a larger, ongoing NOAA (MMS) project “Bowhead Whale Feeding in the Western Beaufort Sea” for which the PIs deployed short-term, shallow oceanographic and year-long marine mammal acoustic recording moorings and conducted additional oceanographic fieldwork during the summer of 2008. Additional components of this larger project include aerial surveys of marine

mammals/bowhead whales, long-term satellite tagging and short-term suction cup tagging of whales to determine migration paths and feeding behavior, and visual observations of whale behavior and locations from small boats. Together these projects provide a greater understanding of the oceanographic conditions off of Barrow as well as providing opportunities to sample over longer time periods in that region in order to better describe the impact of the strength and magnitude of the wind on upwelling along the Beaufort Shelf and the importance of this mechanism to providing prey on the shelf for the bowhead whale. The ongoing project also complements two other NOPP projects "Circulation, Cross-shelf Exchange, Sea Ice, and Marine Mammal Habitats on the Alaskan Beaufort Sea Shelf" led by R. Pickart and including Stafford and Moore as PIs and "A Comprehensive Modeling Approach Towards Understanding and Prediction of the Alaskan Coastal System Response to Changes in an Ice-diminished Arctic" led by W. Maslowski with J. Cassano and J.J. Walsh as co-PIs. The former project focuses on physical oceanography, upwelling, and bowhead whale distribution in a region further to the east of Barrow using a combination of year-long oceanographic and whale acoustic recorder moorings and field observations. Not only does the work of the Pickart NOPP project together with this project extend the spatial range of observations, field logistics were conducted in collaboration. For example, the Healy cruise that deployed moorings for this project also deployed the moorings for the Pickart NOPP in a very fruitful collaboration between the two projects. Several CTD casts were conducted near the Pickart NOPP moorings during the transit of the R/V Annika Marie from Barrow to Prudhoe Bay at the end of the fieldwork of this project. The latter project applies state-of-the-art regional modeling of sea ice, ocean, atmosphere and ecosystem to provide a system approach to advance the knowledge and predictive capability of the diverse impacts of changing sea ice cover on the bio-physical marine environment of coastal Alaska. Hydrography acquired during surveys conducted from the R/V Annika Marie has been forwarded to Maslowski for comparison with model output.

REFERENCES

Lowry, LF, Sheffield G, George JC. 2004. Bowhead whale feeding in the Alaskan Beaufort Sea, based on stomach contents analyses. J. Cet. Res. Man. 6(3): 215–223.

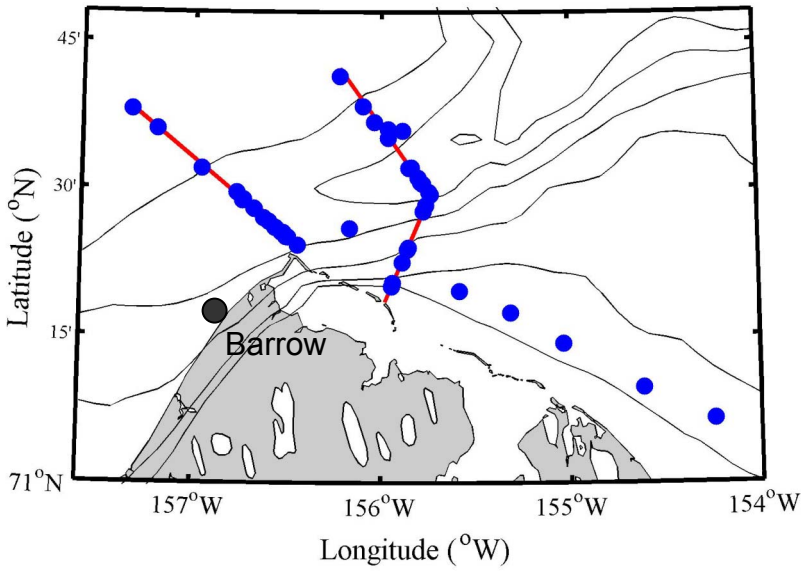

Figure 1. Station locations (blue symbols) and transect lines along which continuous data were collected using the Acrobat and the ADCP (red lines).

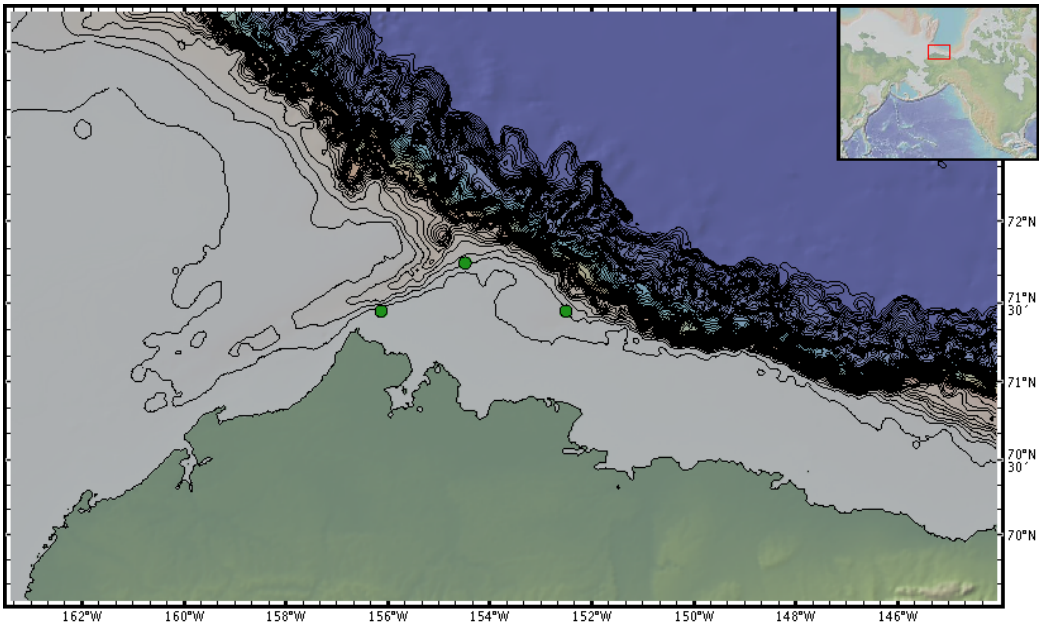

Figure 2. Locations (green circles) of moorings deployed along the Beaufort Shelf break during the Healy cruise and at the edge of Barrow Canyon by the R/V Annika Marie.

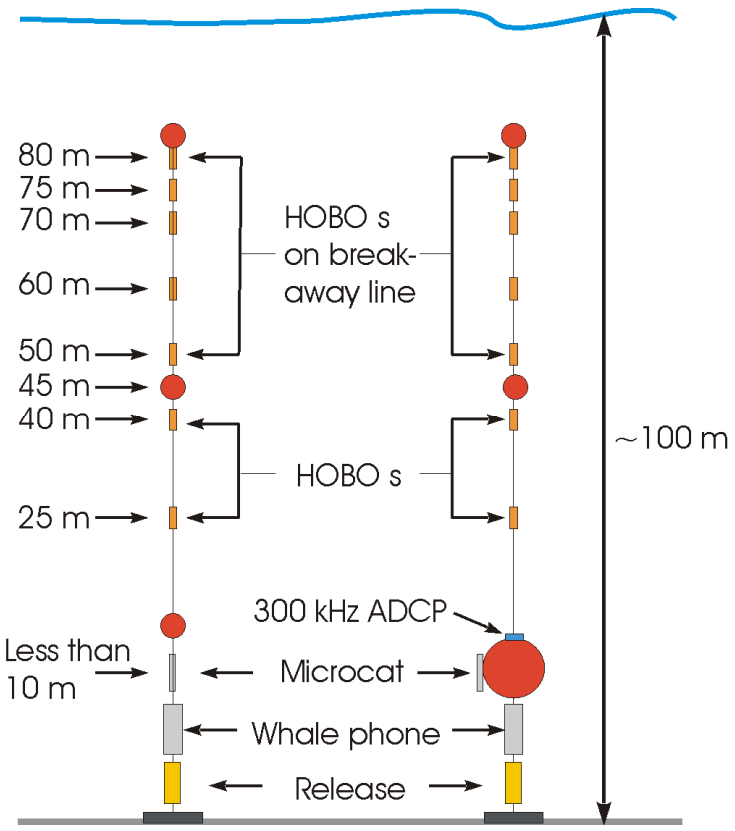

Figure 3. Cartoon of long-term moorings deployed in the Beaufort Sea. The HOBOs are thermistors that record water temperature.

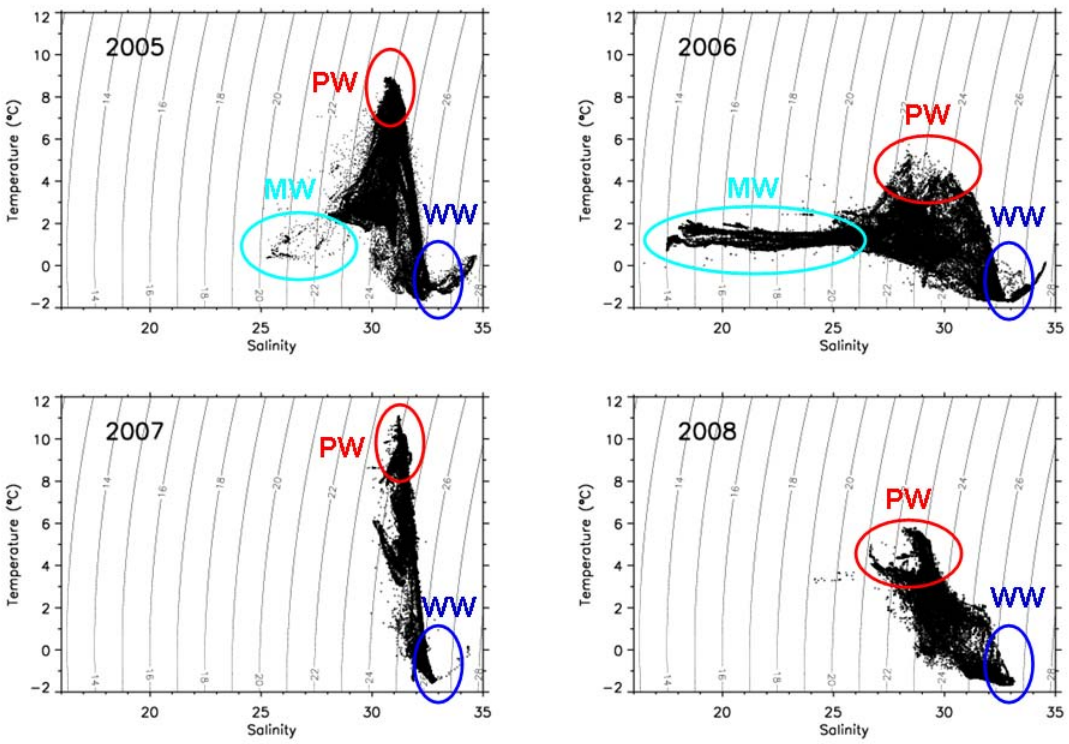

Figure 4. T-S plots of each year's aggregate (Acrobat and individual cast) CTD data. Representative water masses are Pacific Water (PW), Winter Water (WW), and Meltwater (MW). Curved lines are isopycnals (constant sigma-t)

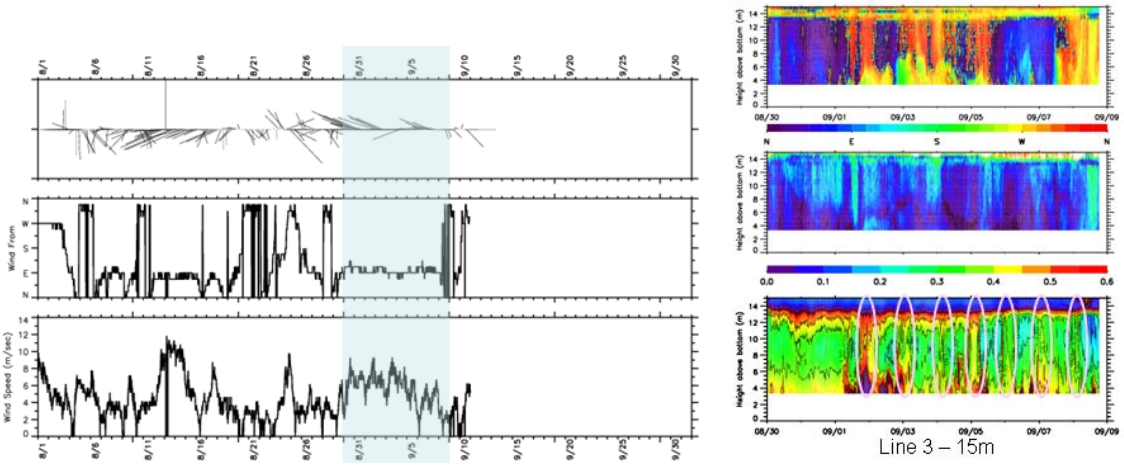

Figure 5. Preliminary data. (Left panels) Winds at Barrow, showing vectors (top), direction (middle), and speed (bottom). August 30 – September 8 are shaded blue. (Right panels) Current direction (top), current speed (middle), and raw acoustic backscatter as counts (bottom) from the short-term mooring at Barrow Canyon for August 30 – Sept. 8. Pink ovals indicate occurrences of inferred diel migration of zooplankton.